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**URBAN AREA DELINEATION AND
DETECTION OF CHANGE ALONG THE
URBAN-RURAL BOUNDARY AS DERIVED
FROM LANDSAT DIGITAL DATA**

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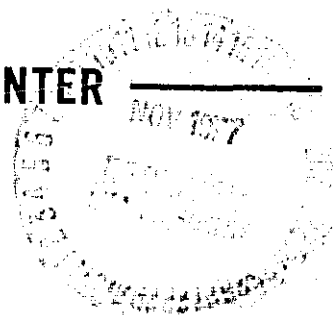
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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND



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ABSTRACT

Landsat digital multispectral scanner data (MSS), in conjunction with supporting ground truth, were investigated to determine their utility in delineation of urban-rural boundaries. The digital data for the metropolitan areas of Washington, D. C., Austin, Texas, and Seattle, Washington, were processed using an interactive image processing system. Processing focused on identification of major land cover types typical of the zone of transition from urban to rural landscape, and definition of their spectral signatures. Census tract boundaries were input into the interactive image processing system along with the Landsat single and overlaid multiple date MSS data. Results of this investigation indicate that satellite collected information has a practical application to the problem of urban area delineation and to change detection.

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URBAN AREA DELINEATION AND DETECTION OF CHANGE ALONG THE URBAN-RURAL BOUNDARY AS DERIVED FROM LANDSAT DIGITAL DATA

INTRODUCTION AND BACKGROUND

Urbanized area (UA) boundaries of major metropolitan areas are part of the decision making criteria for a number of federal funding programs. The delineation of such boundaries performed by the Bureau of the Census every 10 years, is largely determined on the basis of population densities. Originally intended to separate urban and rural populations, the updating of individual urbanized areas has proven useful as a statistical means of measuring the dynamics of urban expansion. Recent legislation and new federal and state program requirements have increased the need for more frequent updates of the urban area boundaries.

According to the Bureau of the Census, their current procedures for updating the boundaries, which are accomplished as part of a national census, are very costly, complicated and time consuming. Multispectral scanner data collected by satellites can provide unbiased and contemporaneous national census information which would allow the professional geographers of the Bureau of the Census to make faster and more accurate decisions concerning the territorial expansion of an urbanized area. In conjunction with other information sources, the satellite data will allow more frequent (intercensal) delineation of UAs and more frequent population estimates.

As part of the 1950 census, urbanized area boundaries were defined block by block in the field by Census Bureau geographers using housing unit counts and population density criteria. This field survey method proved too costly. Thus, for the 1960 census, a new procedure was devised which defined a zone called the "urban fringe zone" (Fig. 1). The urban fringe zone is bounded by two lines; an inner line which indicates an adjusted urbanized area as established in the previous census, and an outer line showing the anticipated extent of urban growth. In the area between the two lines, the urban fringe zone, small enumeration districts were established as a framework for tabulating the fringe zone population density figures. Following an established criteria, each enumeration district was reviewed and either included or excluded from the urbanized area, resulting in an updated urbanized area boundary. In the 1970 census, over 30,000 enumeration districts were reviewed by the Geography Division staff in a period of three months for the 252 urbanized areas in the U. S.

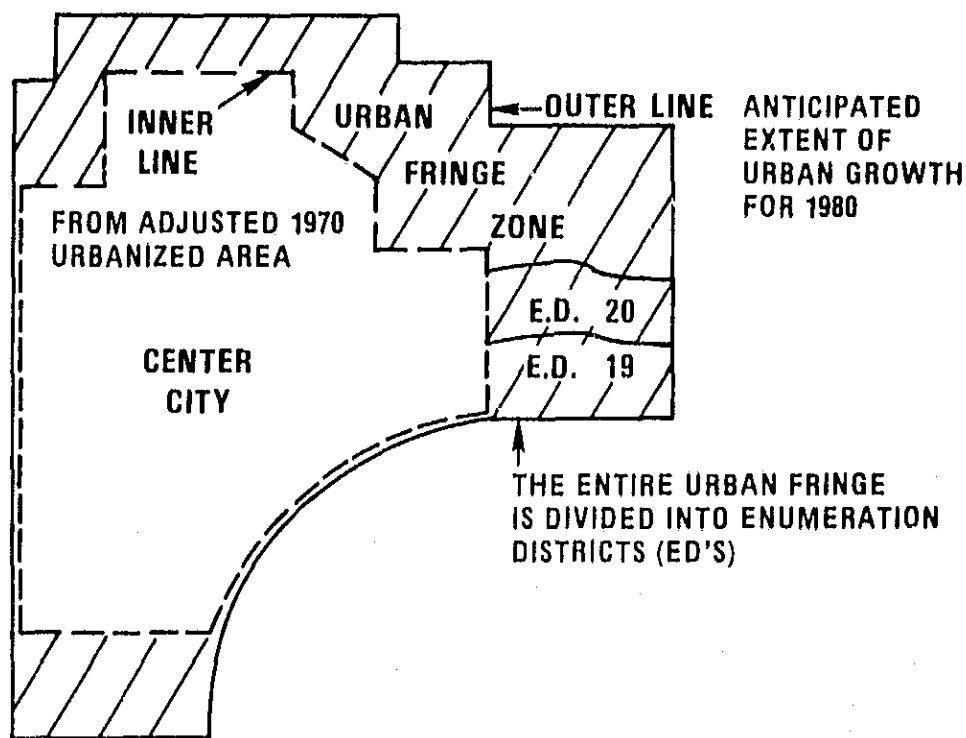


Figure 1. Enumeration Districts Developed in the Urban Fringe Zone for the 1970 Census.

Research described in this paper is directed towards applying satellite data in census-related programs. More specifically, Landsat digital multispectral scanner data are being utilized to define the major land cover types for the built-up areas adjacent to the nation's larger metropolitan centers. This in turn is utilized in the delineation of the urban fringe zone.

METHODS AND PROCEDURES

Landsat 1 and 2 multispectral scanner (MSS) data in digital form was the primary source of information in this project. Imagery (MSS data) for three separate test sites, Washington, D.C.; Austin, Texas; and Seattle, Washington; was selected with specific objectives in mind. In each case several Landsat images from different dates were screened for their geographic coverage, cloud coverage, image quality, and for vegetation growth stage. The latter is a critical factor for proper categorization in some locations of the United States. The best scene or scenes were then analyzed in detail using both batch and interactive multispectral

data analysis systems. Extensive work was done on all three test sites. However, this paper will deal only with the Austin Standard Metropolitan Statistical Area (SMSA)* and with the associated methodology.

Test Site Description

The Austin Standard Metropolitan Statistical Area is located about 120 miles west of Houston, Texas in the transition zone from the Coastal Plain to the Edwards Plateau. The study site encompasses an area about 22 miles in the north-south direction and about 18 miles in the east-west direction. It includes the Austin SMSA and the surrounding areas. The Colorado River flowing in an easterly direction divides the study area roughly in half. The population of the SMSA was about 300,000 in 1970. The growth is occurring mainly north and north-east of the city. The Bureau of the Census is conducting a complete census in Austin this year in order to test new procedures to be used in the 1980 national census. Therefore, because of the extensive field data being collected, Austin is an excellent site to develop satellite data applications for Census activities.

Processing of Landsat Multispectral Scanner Digital Data

Before the machine processing of the multispectral data, the Landsat 1:1,000,000 color composites, and the available ground truth and ancillary information, such as the metropolitan map series, were examined. During this stage, several landmarks and easily identified land cover categories were located on the Landsat images and compared with the available ground truth. The Landsat image boundaries for the Austin test site were also determined. One of the digital data preprocessing techniques consisted of registration of images from two different dates with the cartographic data. The cartographic data were in the form of 7.5 minute USGS topographic maps for the entire study area.

The extraction of thematic information from multispectral data (categorization) was performed on a parallelepiped classification system by statistical measurement of the radiometric properties of the imagery in conjunction with the analyst's visual interpretation. This was accomplished by selecting

*SMSA - Standard Metropolitan Statistical Area is a county or group of contiguous counties which contains at least one city of 50,000 inhabitants or more, or a city of 25,000 inhabitants which with the addition of the population of contiguous places has a combined population of at least 50,000. In addition to the county, or counties, containing such a city or cities, contiguous counties are included in an SMSA if, according to certain criteria, they are socially or economically integrated with the central city.

appropriate training sites for the designated land cover types and performing supervised classification of the MSS data. Special emphasis was placed on the single family residential areas and on new construction sites in the vicinity of the 1970 urbanized area boundary. The resulting thematic maps were then examined on a color CRT display. In addition to the visual interactive display, alphanumeric printouts and digital film recorder outputs were generated and examined.

Establishing the Urban Fringe Zone

Many of the Bureau of the Census activities utilize the urban area statistical data within the framework of census tracts*, of which enumeration districts (ED) are sub-divisions. To make remotely sensed data useful to such activities, it must also be related to these subdivisions. A procedure was developed, with the Bureau of the Census personnel, that would approximate their methods for updating urbanized area boundaries.

The first step was the use of the urban area boundary established during 1970 as the inner line of the 1975 urban fringe zone. The outer line has traditionally been developed from U. S. G. S. topographic maps and the available planning data. The 1975 outer line was established by using the alphanumeric printouts from the categorized Landsat data in conjunction with the traditional data. This procedure created an urban fringe zone for the Austin test site. Included were all the areas surrounding the 1970 urbanized area that exhibited signs of growth (i. e., new residential developments, construction areas, etc.).

Following this, the fringe zone was divided onto a number of enumeration districts (ED) which are regions of contiguous shape with an area greater than one square mile. The ED's and the 1970 urbanized area were overlaid in the interactive image processing system along with the MSS data. This new 1975 data base for Austin provided Landsat categorized land cover data by enumeration district for the Austin urban area.

*Census tracts are small areas into which large cities and adjacent areas have been divided for the reporting of census statistics. Tracts were generally designed to be relatively uniform with respect to population characteristics, economic status, and living conditions. On the average, a tract has about 4,000 inhabitants. Census tract boundaries generally follow visible features such as roads, rivers, railroads, or pronounced physiographic features.

RESULTS AND DISCUSSION

The procedures developed during this project utilize Landsat MSS data as a base that was used on the interactive system for the following:

1. measuring the area of each ED or other subdivision
2. measuring and/or displaying the area categorized as residential/build-up or "other:" within each ED
3. measuring and/or displaying areas categorized into various land cover types for the entire study area.

The above activities can be performed on any type of imagery (satellite or aircraft), as long as the imagery can be registered spatially with the cartographic information.

Statistics generated as a result of the measurements of the individual enumeration districts were printed in a tabular format to list the Landsat categorized data by ED. Color film recorder photographs were generated which show the thematic data plus census data base overlayed on the Landsat imagery. These products are now being utilized by the Bureau of the Census personnel in deciding where and how much change has occurred between 1970 and 1975 as a result of residential expansion. The results will provide a basis to make decisions as to which of the individual enumeration districts will be included or excluded in the 1975 Austin urbanized area.

Using the Landsat derived urban area statistics, there are several additional steps that can be exercised. The number of pixels per enumeration district can be multiplied by a structural density factor, developed from census data, to yield the number of structures per unit area. Once the structural density is determined, the number of persons per structure can be assigned to provide an estimate of population density. This in turn provides the final decision on the location of the urbanized area boundary.

This and other ideas are being incorporated in a larger data base that will allow Census to make periodic adjustments to the urban area boundaries using temporal satellite or aircraft coverage. Spatial registration of two or more data sets (images) acquired several years apart, allows evaluation of changes that occurred in that time. Such changes are being evaluated in the framework of census tracts and other subdivisions.

These techniques for utilizing Landsat data for census activities are being evaluated by the Bureau of the Census. By 1980, the United States will have over three hundred urbanized areas. Estimates for requirements to update the census data base for the urbanized areas range from every two to five years. It is expected that Landsat data will provide vital information for a program to update urbanized areas during the 1980-1990 intercensal period.

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